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Nutritional Studies with *Blattella germanica* (L.) Reared Under Aseptic Conditions

III. Five Essential Amino Acids[1]

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Introduction

Amino acids, the main constituents of protein, are needed by animals for the synthesis of the new body tissue during growth and for the regeneration of old tissues in the adult. They take part in the formation of almost all substances in the body and perform an important function in many physiological processes. When these acids are not available to the animal in sufficient quantities, characteristic metabolic disturbances and pathological conditions result. Amino acids have a similar role in insect physiology and hence have an important bearing upon problems related to insect pathology, toxicology and ecology. Unfortunately, however, very few attempts have been made to investigate the importance of amino acids in the diet of insects.

There is evidence that insects can synthesize some amino acids and that others must be obtained from external sources. It has been shown by Jezewska (1926) that the blow fly, *Musca vomitoria* (presumedly *Calliphora vomitoria* L.) forms tryptophane within the body. Zabinski (1929) claimed that the cockroach, *Blattella germanica* (L.) needs only glycine for its source of dietary nitrogen. On the other hand, there is evidence that other amino acids are essential for growth and development. In both *B. germanica* and the webbing clothes moth, *Tineola bisselliella* Hum., it has been shown that different proteins do not have equal nutritional value (Melampy and Maynard, 1937; McCay, 1938; Crowell and McCay, 1937). This indicates that, in insects, some proteins are not able to satisfy the demand for certain amino acids. Michelbacher, Hoskins and Herms (1932) using the flesh fly, *Lucilia sericata* Meig. proved that immature forms require more cystine than purified casein can supply, and therefore additional cystine is necessary for normal development. Studies with the fruit fly, *Drosophila melanogaster* Meig., have shown cystine, tryptophane, lysine, arginine, histidine and proline to be necessary for normal growth or development (Lafon, 1939; Wilson, 1941; Wilson and Birch, 1944). Lafon (1939) was unable to support the growth of fruit flies on a diet containing a mixture of amino acids from which norleucine and citrulline were omitted and claimed that these or some unknown amino acid must be essential.

It is clearly established that insects require certain amino acids for growth or development. The present work is an attempt to determine which of the amino acids are essential using one species, the German cockroach, *Blattella germanica* (L.).

Materials and Methods

Before suitable experimental diets could be prepared, it was necessary first to formulate, as nearly as possible, a chemically defined diet. This was done as

[1]This investigation was aided by a grant from the Lalor Foundation, Wilmington, Delaware.
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shown by House (1949), through the formulation of a diet consisting of known quantities of purified chemicals including a mixture of amino acids based on casein. This diet is used as the control in the present work. By omitting any one amino acid from the control diet, its composition was altered to provide a number of experimental diets. Using this technique, diets were prepared by which the nutritional importance of tryptophane, valine, cystine, glycine, arginine, histidine and methionine could be determined. Each of these amino acids was in turn omitted from the control diet and the results obtained were compared with those of the control. In order to keep the amount of amino acids constant in all the diets, an additional weight of glutamic acid was added equal to that of the constituent withheld. These diets were carefully prepared and sterilized for the nutritional assays.

The experiments were conducted under aseptic conditions throughout using equipment and methods described by House and Patton (1949). Nymphs of *B. germanica* were obtained free from microorganisms and used as test animals. These were reared individually in a darkened room at a temperature of 29.5 ± 0.5°C. and a relative humidity of approximately 70%. Each experiment was carried on for twelve weeks, during which each nymph was weighed at regular weekly intervals in order to measure its weight increment. This provided a means for studying the effects of experimental diets on the growth and development of the insects over the entire assay period. The nymphs also were tested to detect the presence of microorganisms using customary bacteriological techniques. The records of any individual found to be contaminated were omitted in evaluating the results.

Growth data on the aseptic nymphs provided the basis for determining differences between the weight of insects reared on the control diet and those reared on the experimental diets. The differences were considered to be due to the deficiency of amino acids omitted from the experimental diets. Each experiment was designed on a statistically analysable basis and treated by an analysis of variance as outlined by Paterson (1939). Only the weights of aseptic nymphs alive at the end of the assay period were included in the growth data. Both sexes of the insect were present in nearly equal numbers and therefore did not significantly affect the results, although the females usually weighed more than the males.

Results

The results of the series of nutritional studies are summarized in Tables I and II.

Discussion

Considerable growth took place on all the diets but significant differences were evident between the different rates of growth. The differences were evaluated by the analysis of variance using the growth data at the eighth and twelfth week. Comparisons were made between the mean weights of the insects reared on the control diet and the weights of the insects on each diet lacking one of the amino acids. Calculations made from the growth data gave a positive result according to the *F* test used to compare component variates. It was found that at *t* 0.01 and 198 degrees of freedom differences are statistically significant between the mean weights of the treated nymphs when the differences are greater than 5.0 mgm. at the eighth week and 11.7 mgm. at the twelfth week. The differences between the means of the control diet and each experimental diet, as well as the significance of the differences are shown in Table III.

TABLE I

Weekly mean weights of cockroaches in mgm.

Weeks	Diets													
	Control	–Valine		–Trypto-phane		–Cystine		–Glycine		–Arginine		–Histidine		–Methio-nine	
1	2.7±0.1	2.5±0.1		2.4±0.1		2.3±0.1		2.3±0.1		2.1±0.1		2.0±0.1		2.3±0.1	
2	3.7 0.1	2.5 0.2		2.8 0.2		3.0 0.2		3.3 0.2		3.0 0.2		2.6 0.2		3.4 0.2	
3	5.3 0.3	3.3 0.2		3.6 0.2		4.4 0.4		5.0 0.3		3.9 0.2		3.7 0.2		4.6 0.4	
4	7.3 0.3	4.7 0.3		4.5 0.3		7.0 0.6		6.3 0.6		5.5 0.3		5.5 0.2		5.8 0.4	
5	10.1 0.5	6.5 0.4		5.6 0.4		8.5 0.7		8.8 0.8		7.1 0.4		7.4 0.5		8.0 0.6	
6	12.6 0.6	8.5 0.6		7.3 0.6		12.0 1.0		11.7 1.2		9.4 0.6		9.7 0.6		11.1 1.0	
7	16.7 0.8	10.9 0.7		9.3 0.6		15.0 1.5		13.6 1.5		13.0 1.0		12.2 0.5		13.4 1.2	
8	20.5 0.9	13.4 0.9		12.6 1.0		20.6 2.2		20.2 2.0		15.2 1.2		14.4 1.4		17.6 1.9	
9	25.8 1.4	16.7 1.0		15.6 1.0		27.1 3.5		24.3 2.4		19.6 1.6		18.6 1.5		21.6 2.3	
10	31.2 1.7	20.0 1.4		19.4 1.6		33.9 3.4		31.7 3.8		25.9 2.1		22.2 2.0		27.9 3.6	
11	40.4 2.1	25.5 2.1		23.5 2.0		36.7 4.3		39.5 4.0		31.6 2.1		24.7 2.4		32.5 3.4	
12	43.9 2.4	31.5 2.5		30.0 2.4		42.6 4.7		45.5 5.0		36.9 2.9		29.8 3.3		39.0 3.7	

TABLE II

Rearing records of nymphs fed on different experimental diets.

Diets	Number of individuals		Mortality %	Length of assay (weeks)	Appearance of first adult		Adults appearing during assay		
	Initial	Final			Week	Sex	Sex		Percentage of initial number
–Control	41	35	14.6	12	11	2♂	5♂	4♀	21.9
–Valine	39**	32	15.8	12	0	0	0		0
–Tryptophane	39**	31	18.4	12	11	1♂	2♂		5.3
–Crystine	28	16	42.9	12	9	1♂	6♂	2♀	28.6
–Glycine	25	21	16.0	12	10	1♂	3♂	6♀	36.0
–Arginine	28	24	14.3	12	11	1♂	4♂		14.3
–Histidine	27	25	7.4	12	10	1♂	1♂	1♀	7.4
–Methionine	25	22	12.0	12	11	2♂ 3♀	2♂	3♀	20.0

**1 contaminated (disqualified).

TABLE III

Difference between the weight of nymphs reared on the experimental and control diets.

Diets	Eighth Week			Twelfth Week		
	Mean weight of insects (mgm.)	Difference from control (mgm.)	*P** Value	Mean weight of insects (mgm.)	Difference from control (mgm.)	*P* Value
–Control	20.5			43.9		
–Valine	13.4	7.1	< 0.01	31.5	12.4	< 0.01
–Tryptophane	12.6	7.9	< 0.01	30.0	13.9	< 0.01
–Cystine	20.6	0.1	> 0.5	42.6	1.3	> 0.5
–Glycine	20.2	0.3	> 0.5	45.5	2.6	> 0.5
–Arginine	15.2	5.3	< 0.01	36.9	7.0	> 0.5
–Histidine	14.4	6.1	< 0.01	29.8	14.1	< 0.01
–Methionine	17.6	2.9	> 0.5	39.0	4.9	> 0.5

*The *P* value is considered to be significant when it is less than 0.01.

The growth curves of the nymphs fed on the different diets are illustrated in Figs. 1 and 2. It is clear that the differences between the growth of nymphs reared on the control diet and those reared on diets lacking either valine, trytophane or histidine are quite significant at the twelfth week and it is highly probable that arginine can be included with the group at the eighth week. Hence, it is believed that valine, tryptophane, histidine and probably arginine need to be present in the diet for the normal growth of *B. germanica.*

The amino acids valine, tryptophane, histidine and arginine are among those whose essentiality has been established in the rat, dog, mouse and chick, (Rose, 1938; Rose and Rice, 1939; Baur and Berg, 1943; Hegsted, Briggs, Elvehjem and Hart, 1941). Although synthesized in the rat, arginine is not formed at a rate commensurate with normal growth. It has already been pointed out that among insects, *D. melanogaster* needs tryptophane, histidine and arginine for growth and/or development. With *B. germanica* it appears that valine, tryptophane, histidine and arginine are not absolutely indispensable, since the absence of any one of them from the diet did not prevent considerable growth. The missing dietary amino acid in these cases is probably synthesized to some extent by the cockroach through the metabolism of other amino acids. There is the possibility, however, that the intervention of intracellular symbionts may also provide the amino acids which are lacking in the diet of the insect.

The unpublished work of Auclair and Pratt[1] has shown that some amino acids are formed in the cockroach. These workers were also studying the importance of amino acids in insects while the present work was in progress. They analysed the blood of nymphs reared on each diet for free amino acids by means of the chromatographic technique of Consden, Gordon and Martin (1944). It was found that when either valine, arginine or glycine was omitted

[1]Auclair, J. L., and Pratt, J. J. Research Fellows, Lalor Foundation at Cornell University.

from the diet of the insect, the missing dietary amino acid was present in the free state in the blood. If histidine, tryptophane, cystine or methionine were omitted, none was found free in the blood. This is based, however, on only one observation.

Methionine, although essential in the rat (Rose, 1938), does not appear to be required by the German cockroach. The presence of choline in the diet may have diverted any clear evidence of a requirement for this amino acid since choline can supply methyl groups, and by transmethylation, methionine may be formed *in vivo* (Hawk, Oser and Summerson, 1947).

The results obtained when cystine was omitted also present an interesting problem. From previous feeding tests it was found that the growth of nymphs was more rapid on non-aseptic than on aseptic diets. Both diets were identical in composition and contained purified casein, but the difference in the rate of growth of the insects reared on them indicated a deficiency. The deficiency, however, was not brought about by the destruction of a nutritive factor in the food by autoclaving. After a period of retarded growth on a diet containing casein a considerable mortality (34.3%) was observed, but some nymphs showed growth comparable to those reared on the control diet (House, 1949). Under somewhat similar conditions Michelbacher, Hoskins and Herms (1932) have shown that cystine, occurring at a low level in casein, is essential for *L. sericata*. In view of these observations it seems very likely that cystine is involved in the nutrition

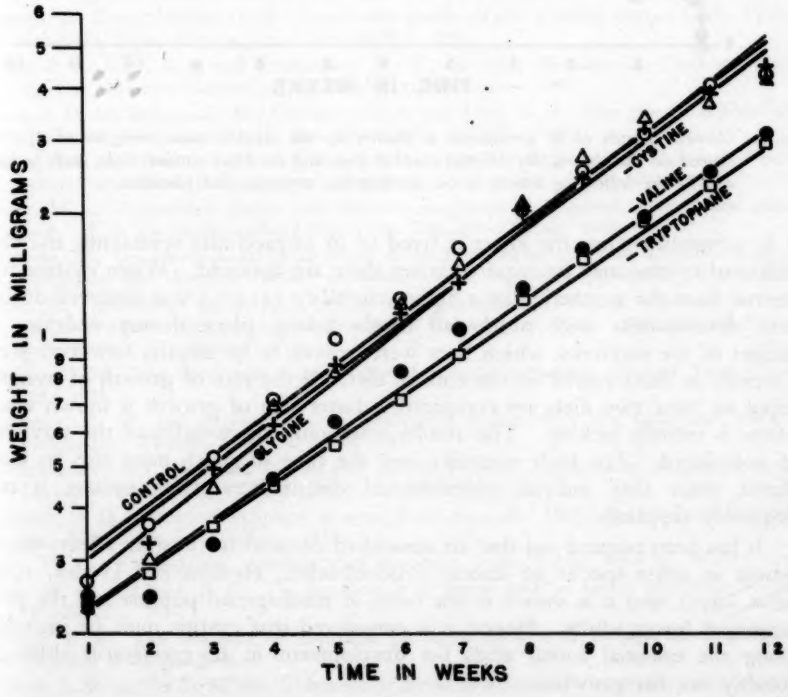

FIG. 1. Growth trends of *B. germanica* as shown by the weekly mean weights of nymphs reared on the chemically defined control diet, and on four similar diets, each lacking one of the following amino acids; cystine, glycine, valine, and tryptophane.

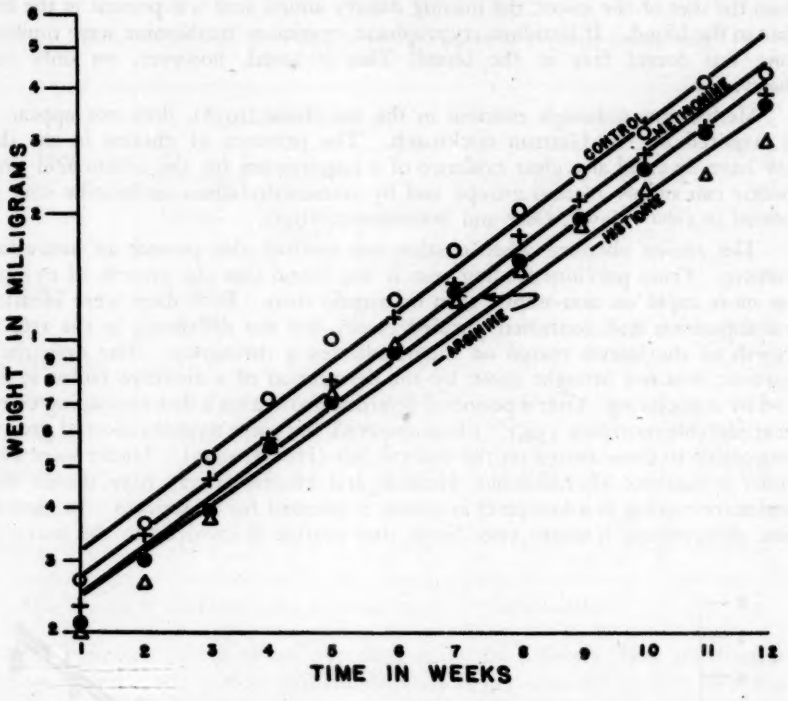

FIG. 2. Growth trends of *B. germanica* as shown by the weekly mean weights of nymphs reared on the chemically defined control diet, and on three similar diets, each lacking one of the following amino acids: methionine, arginine, and histidine.

of *B. germanica* when the insect is freed of its extracellular symbionts, and that additional cystine may be required when these are removed. When cystine was omitted from the synthetic diet a higher mortality (42.9%) was observed during early development with nearly all deaths taking place during ecdysis. A number of the survivors, which later were proven to be aseptic, however, grew as rapidly as those reared on the control diet. If the rate of growth of nymphs reared on these two diets are compared, a faster rate of growth is shown when cystine is entirely lacking. This results when only the weights of the survivors are considered. The high mortality and the time of death must also be considered, since they indicate physiological disturbances when cystine is not adequately supplied.

It has been pointed out that an unsatisfied demand for cystine affects development in other species of insects (Michelbacher, Hoskins and Herms, 1932; Lafon, 1939), and it is shown in the form of misshapened puparia and the production of fewer adults. Hence, it is considered that cystine must be included among the essential amino acids for development in *B. germanica*, although probably not for growth.

From the results of this work it is concluded that the amino acids valine, tryptophane, histidine and probably arginine are necessary for normal growth of the cockroach, *B. germanica*. Cystine is essential for development in this

species, particularly during its early instars. Neither growth nor development is affected when either glycine or methionine is omitted from the diet.

The experiments reported in this series were conducted at the Department of Entomology, New York State College of Agriculture, Cornell University, where they were presented as a thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy. Grateful acknowledgment is made to Dr. R. L. Patton under whose direction the work was undertaken, for his valuable suggestions and advice and to Dr. C. Lalor Burdick and the Lalor Foundation of Wilmington, Delaware, whose interest and support made this study possible.

Summary

A series of experiments were carried out under aseptic conditions to determine the nutritional importance of the amino acids valine, tryptophane, cystine, glycine, arginine, histidine and methionine. Of these, it was shown that valine, tryptophane, histidine and probably arginine are essential for normal growth. Cystine appears to be essential for development. Neither growth nor development is affected when either glycine or methionine is omitted from the diet.

References

Baur, C. D. and Berg, C. P. The amino acids required for growth in mice and the availability of their optical isomers. *J. of Nut., 26*: 51-63. 1943.

Consden, R., Gordon, A. H. and Martin, A. J. P. Qualitative analysis of proteins; a partition chromographic method using paper. *Biochem. J., 38*: 224-262. 1944.

Crowell, M. F. and McCay, C. M. Nutritional studies of the webbing clothes moth, *Tineola bisselliella, Hum. Physiol. Zool. 10*: 368-372. 1937.

Hawk, P. B., Oser, B. P. and Summerson, W. H. Practical Physiological Chemistry. 12th ed. The Blakiston Company, Philadelphia and Toronto. 1947.

Hegsted, D. M., Briggs, G. M., Elvehjem, C. A. and Hart, E. B. The role of arginine and glycine in chick nutrition. *J. Biol. Chem. 140*: 191-200. 1941.

House, H. L. and Patton, R. L. Nutritional studies with *Blattella germanica* (L.) reared under aseptic conditions. I Equipment and technique. *Can. Ent. 81*: 94-100. 1949.

House, H. L. Nutritional studies with *Blattella germanica* (L.) reared under aseptic conditions. II. A chemically defined diet. *Can. Ent. 81*: 105-112. 1949.

Jezewska, M. Les changements de la teneur en tryptophane au cours du developpement des chrysalides des Mouches (*Musca vomitoria*).—*C.R. Soc. Biol. Paris. 95*: 910-912. 1926.

Lafon, M. Recherches sur quelques aspects du besoin qualitatif d'azote. Essai sur le besoin qualitatif d'azote chez un insecte: *Drosophila melanogaster*, Meig. *Ann. Physiol. Physiocochim. biol. 15*: 215-260. 1939.

McCay, C. M. The nutritional requirements of *Blattela germanica. Physiol. Zool. 11*: 89-103. 1938.

Melampy, R. M. and Maynard, L. A. Nutrition studies with the cockroach (*Blatella germanica*). *Physiol. Zool. 10*: 36-44. 1937.

Michelbacher, A. E., Hoskins, W. M. and Herms, W. B. The nutrition of flesh-fly larvae, *Lucilia sericata*, Meig. *J. Expt. Zool. 64*: 109-128. 1932.

Paterson, D. D. Statistical technique in agricultural research. McGraw-Hill Book Company, Inc., New York and London. 1939.

Rose, W. C. The nutritive significance of the amino acids. *Physiol. Rev. 18*: 109-136. 1938.

Rose, W. C. and Rice, E. E. The significance of amino acids in canine nutrition. *Science, 90*: 186-187. 1939.

Wilson, L. P. The influence of *L*-proline on larval growth in *Drosophila melanogaster. Growth, 5*: 11-18. 1941.

Wilson, L. P. and Birch, M. M. Tolerance of larvae of *Drosophila* for amino acids: arginine. *Growth, 8*: 125-148. 1944.

Zabinski, J. The growth of blackbeetles and of cockroaches on artificial and on incomplete diets. *Brit. J. Expt. Biol. 6*: 360-385. 1929.

A Study of the Male Hypopygia of the Species of *Tubifera* (Syrphidae, Diptera) That Occur North of Mexico

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During a study of the species of *Tubifera* known to occur in Maine the author noted that certain specific key characters were not always constant, and often a long series of several species was required before identification was certain. In search of taxonomic characters to supplement those given in literature the author extracted and compared the male hypopygia of several known species of *Tubifera*. It soon became apparent that this structure deserved more emphasis in the taxonomy of this interesting genus.

The primary purpose of this study was to determine whether or not the hypopygia of the species of *Tubifera* possess characters of value in classification, and, if so, how valuable and accessible these characters are to the general worker. Metcalf (1921) found that the hypopygia of the Syrphidae afford constant and ready characters which may at times be of decided value to the specialist in the determination of closely related species. Hence it was natural to expect that a study of the hypopygia of the genus *Tubifera* might aid in a better understanding of the numerous species in the genus.

In addition to the reason already stated, there are certain general considerations which would lead one to expect such an investigation as this to be fruitful. The taxonomist is always in search of constant characters sufficiently definite to separate closely related species, and yet present in the entire range of the species. Because of their internal position the hypopygia are more likely to be constant than external structures, which may vary with difference in environment.

By hypopygia is meant the group of appendages at the caudal end of the abdomen, surrounding the sexual and anal orifices of the male insect. Their dominant function is the reproductive one of mating, but they are also involved to some extent in defecation and sensation.

Technique for Preparing Specimens

At the beginning of this study the author had no knowledge of the structures present in the hypopygium which would be of use to the taxonomist; therefore, slides were made of the entire group of postabdominal appendages beginning with the eighth segment. These appendages were soaked in caustic potash—ten percent, for twenty-four hours, washed thoroughly in water, dehydrated in alcohol, cleared in xylol, and mounted in balsam.

Following the examination of several species it became evident that the characters furnished by the lobes of the aedeagus, and the shape of the surstyli, were variable between species yet constant within the same species. The cerci, although less variable, were found useful in certain cases. The author then used three other methods in preparing the hypopygium for study. They were easier to use and also enabled him to examine the parts from different angles. On freshly killed specimens the postabdominal parts were carefully pulled out from their normally retracted position and the parts held fully exposed with insect pins until dry. It is essential that the lobes of the aedeagus be fully exposed as they furnish important taxonomic characters. On old specimens the above method is sometimes difficult unless the specimen is thoroughly relaxed. With these specimens the author was often forced to remove the entire postabdominal appendages at the juncture of the seventh and eighth segment, and preserve the

part removed in a small vial containing equal parts of water, glycerin, and 95 percent alcohol. The small vial was then attached to the pin holding the insect from which the appendage was removed, thus preventing any errors in the preparation of the key. The third and final method was used more often than the other two. In this method the postabdominal appendages were removed as above. An insect pin was then inserted between the aedeagus and the surstyli so as to expose the apical portion of the aedeagus and then put away to dry. After the hypopygium was thoroughly dried the pin was carefully removed and the structure glued to a small cardboard point in such a manner that all parts could be readily seen. The cardboard point was then pinned inside a small gelatin capsule using the pin holding the insect from which the appendage came.

Illustrations

The figures for this paper were drawn with two objects in mind: first, to exhibit the characteristic structures useful to taxonomists in determining the species, and, secondly, to give, as far as possible, an ensemble of all structures dealt with in this paper. In some cases, the fine characters on certain portions of the lobes are shown, separately, much enlarged. All figures were drawn from a lateral view with the aid of a camera lucida at approximately 75 magnifications. The drawings were then photographed for use in this paper.

Terminology of Parts

The terminology used in this paper has been adapted from Crampton (1942), except in the designation of the lobes of the aedeagus. For these the terminology suggested by Metcalf (1921) has been used. (See fig. 1).

Aedeagus—The rigid, heavily sclerotized structure which serves to guide and protect the membranous penis.

Anterior—Toward the head of the insect.

Apex—That part of the structure opposite or farthest removed from the base by which it is attached.

Base—The point of attachment to or nearest the main body.

Cerci—The paired appendages of the tenth abdominal segment.

Dorsal—The upper surface or margin farthest away from the cerci.

Inferior lobes—The more cephalad of the two pairs of lobes or appendages arising from the apex of the aedeagus.

Lateral—Toward the side and away from the median line.

Medial—Of or pertaining to the middle.

Posterior—Opposed to anterior.

Superior lobes—The more caudad of two pairs of lobes or appendages arising from the apex of the aedeagus.

Surstyli—The paired appendages of the ninth abdominal tergite.

Ventral—Opposed to dorsal, or that surface or margin nearest the cerci, but not that which is attached to a urite.

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parative Zoology for their generous loan of numerous specimens without which this study would have been impossible.

Species Not Included

Due to the large number of species known to occur in this genus, and the difficulty in obtaining specimens, only those species known to occur north of Mexico have been included in this study. The author regrets that he was unable to secure specimens of the following species recorded as occurring within this region: *inornatus* Loew, *mellissoides* Hull, *oestraceus* Linne, *parens* Bigot, *ornatus* Townsend, and *texanus* Hull.

Nomenclature of Genus

The generic name *Tubifera* Meigen, 1800 (genotype: *Musca tenax* Linnaeus) is used in place of *Eristalis* Latreille, 1904 (genotype: *Musca tenax* Linnaeus) because it has priority over the latter name. Stone (1941) showed that *Tubifera* Meigen and *Eristalis* Latreille are isogenoptypic and that *Eristalis* must fall as a synonym of *Tubifera.*

Key to Species Based Upon the Male Hypopygium

1. Apex of each superior lobe with a prominent lateral upcurved horn, denticulate at apex and blackly chitinized (fig. 4) ..... *agrorum* Fabr.
   Apex of each superior lobe without lateral horn 2
2. Each inferior lobe broadly inflated, hood-like, not horn shaped; slightly sunken into dorsal surface of aedeagus 3
   Each inferior lobe distinctly horn-shaped, long, with dorsal margin swollen and heavily chitinized; curved laterally over dorsal margin of aedeagus 6
3. Each superior lobe spade-shaped, nearly as broad at base as long, with a prominent lateral upturned fold near apex 4
   Each superior lobe much longer than wide at base; gradually tapering to a bluntly rounded apex 5
4. Each superior lobe with apex of upturned fold bluntly rounded. Dorsal margin of each surstylus with a broad medial lobe (fig. 2) ..... *pusillus* Macq.
   Each superior lobe with apex of upturned fold denticulate. Dorsal margin of each surstylus with a long, narrow lobe near base (fig. 3) ..... *albifrons* Wd.
5. Each surstylus broadly lobed on dorsal margin near base; apex projecting posteriorly. Cerci short and broad (fig. 5) ..... *arbustorum* L.
   Each surstylus not lobed on dorsal margin near base, but slightly constricted medially and club-shaped; apex projecting nearly perpendicular to the dorsal margin of the 9th tergite. Cerci long and narrow (fig. 6) ..... *brousi* Will.
6. Dorsal margin of each surstylus cleft in such a manner as to form one or more distinct lobes 7
   Dorsal margin of each surstylus not cleft, but sinuous or undulate; sometimes forming a broad medial hump, or a sharp hook near base of apical third 13
7. Each superior lobe knife-like in lateral view; long, tapering to a slightly upturned point; dorsal margin heavily chitinized (fig. 7) ..... *latifrons* Lw.
   Each superior lobe truncate or rounded at apex, not knife-like 8
8. Dorsal margin of each surstylus with a deep wide cleft nearly bisecting structure; apex elongate, pointed, and recurved 9
   Dorsal margin of each surstylus narrowly cleft, sometimes forming two distinct lobes basad of apex; apex nearly as broad as long, slightly curved inwardly over cercus 10
9. Dorsal margin of each superior lobe with a slight medial fold giving rise to a triangular shaped projection finely serrated along apical margin. Apex of superior lobe spade-shaped with serrations along dorsal margin. Each inferior lobe broad at base and gradually tapering to apex (fig. 8) ..... *vinetorum* Fabr.
   Dorsal margin of each superior lobe without fold or projection. Apex of superior lobe truncate, slightly extended at ventral margin forming a rounded spur. Apical margin serrate. Each inferior lobe broadly swollen at base with apical two-thirds narrowly constricted, long, spur-like (fig. 9) ..... *obsoletus* Wd.
10. Dorsal margin of each surstylus cleft in such a manner as to form two distinct lobes; apical lobe very small and finger-like 11
    Dorsal margin of each surstylus deeply and narrowly cleft medially, but not as above 12

11. Each superior lobe nearly as broad at apex as at base; apex broadly rounded with a large dorsal notch (fig. 10) ..... *transversus* Wd.
Each superior lobe less than a third as broad at apex as at base; apex slightly upturned with a small dorsal notch (fig. 11) ..... *dimidiatus* Wd.
12. Apex of each superior lobe squarely truncate with fine serrations along dorsal and apical margin. Dorsal margin of each surstylus with a broad V-shaped cleft (fig. 13) *pilosus* Lw.
Apex of each superior lobe broadly rounded with a shallow notch near dorsal margin, serrated below. Dorsal margin of each surstylus deeply incised (fig. 14) *compactus* Wlk.
13. Apex of each superior lobe diamond-shaped, sharp-pointed, and constructed at base of apical third; coarsely serrated along dorso-apical margin (fig. 12) ..... *bastardii* Macq.
Apex of each superior lobe rounded or truncate, not pointed 14
14. Each superior lobe very short, no longer than broad; finely serrated along apical margin; dorsal margin produced at apex into a short rounded undulate spur (fig. 15) ..... *tenax* L.
Each superior lobe at least twice as long as wide 15
15. Each superior lobe gradually tapering to the long, narrow, bluntly rounded apex; apex less than one-half the width at the base (fig. 16) ..... *rupium* Fabr.
Apex of each superior lobe as wide as, or at least two-thirds the width of base 16
16. Dorsal margin of each surstylus with a broad medial lobe that is as wide as broad at base (fig. 17) ..... *nemorum* (L.)
Dorsal margin of each surstylus undulate, but without a distinct medial lobe 17
17. Apex of each surstylus swollen in such a manner as to form a large conical lateral lobe. Inner surface of surstylus broadly and deeply concaved 18
Apex of each surstylus without conical lobe on lateral surface, although the apical margin may be slightly swollen. Not or but slightly concaved on inner surface 19
18. Each superior lobe gradually tapering to a narrowly truncate apex. Apical half curved upward with a small, curved, dorsal spur near apex. Margin beyond spur and at apex serrate (fig. 19) ..... *saxorum* Wd.
Each superior lobe broader medially than at base or apex, ellipsoidal in shape. Apex truncate with margin slightly concave and serrate, without dorsal spur (fig. 20) *obscurus* Lw.
19. Each superior lobe constricted medially, widen at apex, curved downward (fig. 18) *flavipes* Wlk.
Each superior lobe not constricted medially, straight, not curved downward; sometimes with a dorsal spur (fig. 21) ..... *hirtus* Lw. (*temporalis* Thomson)

Discussion of Species

Genus *Tubifera*

1800 *Tubifera* Meigen, Nouv. Class. des Mouches à deux Ailes, p. 34. Type, *Musca tenax* L.

1803 *Elophilus* Meigen, Illiger's Mag. 2: 274. Type, *Eristalis tenax* (F.)= *Syrphus tenax* (F.))=*Musca tenax* L.

1804 *Eristalis* Latreille, Hist. Nat. des Crust. et Ins., 24: 194. Type, *Musca tenax* L.

Tubifera alhambra (Hull)

1925 *Eristalis alhambra* Hull, Ohio Jour. Sci., 25: 39.

1930 *Eristalis alhambra* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: California.

Through the courtesy of Dr. Bequaert the author had available for study a topotype of this species. The characters of this specimen agree with Hull's (1925) description, and it keys to this species in Curran's (1930) key. Although this specimen is separated from the available specimens of *agrorum* (Fab.) by having the mesonotum wholly gray in front of the suture, the hypopygia are identical. The denticulation at the apices of the horns of the superior lobes were found to be variable in both species.

A single specimen, topotype, from Redlands, California was available for study.

Tubifera agrorum (Fabricius) (Fig. 4)

1787 *Syrphus agrorum* Fabricius, Mant. Insect. II, p. 335.

1805 *Eristalis agrorum* Fabricius, Syst. Antl., p. 235.

1842 *Eristalis cubensis* Macquart, Mem. Soc. Sci. Lille, p. 102.
1925 *Eristalis agrorum* Hull, Ohio Jour. Sci., 25: 288.
1930 *Eristalis agrorum* Curran, Amer. Mus. Nov., 411: 17.

Distribution: This species is widely distributed south of the Mexican border, but occurs only rarely in our Southern States.

The prominent, blackly chitinized, dorsally curved, denticulate horn at the apices of the superior lobes will readily distinguish this species. At the base of each horn, apically, there is a rounded, coarsely punctuate, translucent process. Inferior lobes hood-like, rounded on dorsal surface and concave on inner surface, curved laterally over dorsal margin of aedeagus. Surstyli long, narrow, and slightly constricted at basal third; apices paw-shaped and curved inwardly over superior lobes. Outer surfaces of surstyli with numerous coarse, black, spine-like hairs. These hairs are longer near base of ventral margins. The inner surfaces of the surstyli are concave and covered with short black spines.

Males examined from the following localities: Orlando, Florida and Patilla Pt., Canal Zone.

***Tubifera pusillus* (Macquart) (Fig. 2)**

1842 *Eristalis pusillus* Macquart, Mem. Soc. Sci. Lille, p. 114.
1925 *Eristalis pusillus* Hull, Ohio Jour. Sci., 25: 36.
1930 *Eristalis pusillus* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: This species is fairly common below the border, but north of Mexico it is recorded only from Texas.

The close relationship between this species and *albifrons* (Wied.) is indicated in the general shape of the hypopygium. The broadly inflated inferior lobes, the lateral upturned fold of the superior lobes, and the lobed dorsal margin of the surstyli support this relationship. In the separation of the two species the characters afforded by the superior lobes and surstyli are most specific.

Only a single specimen from Omilteme, Guerrera (AMNH) was available for study.

***Tubifera albifrons* (Wiedemann) (Fig. 3)**

1830 *Eristalis albifrons* Wiedemann, Auss. Zweifl. Ins., 2: 189.
1886 *Eristalis albifrons* Williston, Synop. N. A. Syrph., p. 177.
1925 *Eristalis albifrons* Hull, Ohio Jour. Sci. 25: 35.
1930 *Eristalis albifrons* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Known from Louisiana and Florida.

The distinct shape of the superior lobes in this species will at once separate it from the other species of this genus. The apical portions of the superior lobes have a broad upturned, lateral fold similar to that found in *pusillus*, except that the apex of the fold in *albifrons* is coarsely denticulate.

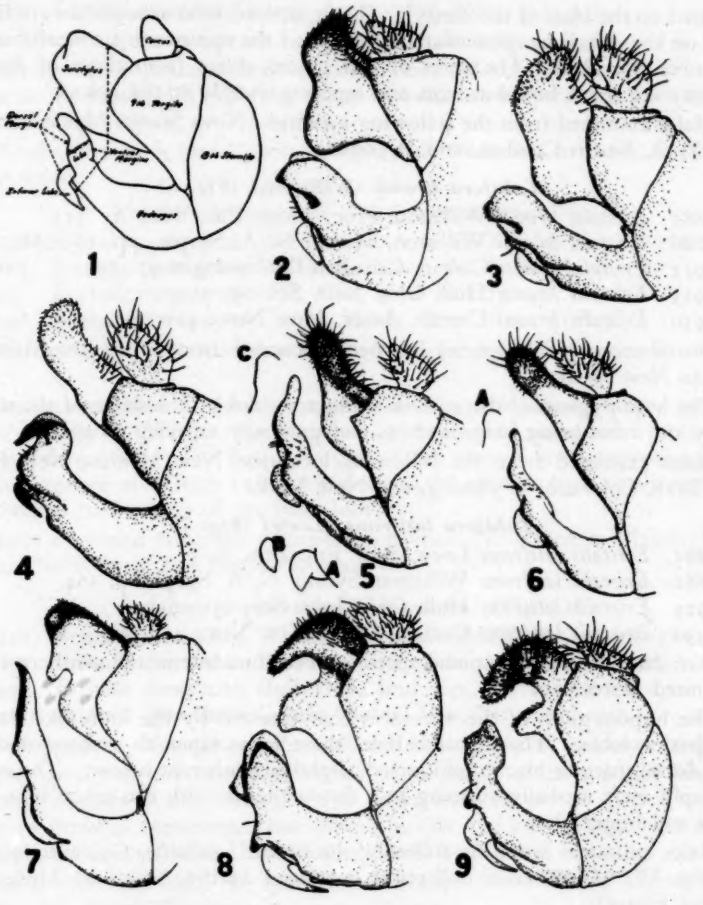
Males examined from the following localities: Palm Beach, Florida and Barro Colorado, Canal Zone.

***Tubifera arbustorum* (Linne) (Fig. 5)**

1758 *Musca arbustorum* Linne, Syst. Nat., 10th ed., p. 591.
1925 *Eristalis arbustorum* Hull, Ohio Jour. Sci. 25: 309.
1930 *Eristalis arbustorum* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Widely distributed over the United States.

The hypopygia of *arbustorum*, *brousi* (Will.), *pusillus* and *albifrons* differ very markedly from all other species in this genus by the distinctive shape of the inferior lobes. *E. arbustorum* and *brousi* are separated from *pusillus* and *albifrons* by the shape of the superior lobes which are long, narrow, and taper



HYPOPYGIA OF TUBIFERA

Fig. 1. A diagrammatic representation of the various parts of the male hypopygium used in this study.
2. *Tubifera pusillus* (Macq.)
3. *Tubifera albifrons* (Wied.)
4. *Tubifera agrorum* (Fabr.)
5. *Tubifera arbustorum* (Linné); A. inferior lobe—lateral view; B. same—dorsal view; C. dorso-apical margin of a superior lobe.
6. *Tubifera brousi* (Will.); A. apex of a superior lobe.
7. *Tubifera latifrons* (Loew)
8. *Tubifera vinetorum* (Fabr.)
9. *Tubifera obsoletus* (Wied.)

toward the apices. *E. rupium* (Fabr.) has superior lobes somewhat similar, but the broad, notched surstyli, and the thin leaf-like inferior lobes readily separate the species. The separation of *arbustorum* from *brousi* is somewhat more difficult. The close relationship of these two species can be seen in the shape of the aedeagus, but by carefully studying figures 5 and 6, the two species can be

separated on the basis of the surstyli. These structures in *arbustorum* are broadly lobed on the dorsal margins near the base, and the apices project nearly straight back over the cerci. The cerci of this species differ from those of *brousi* in that they are short, broad at base, and tapering sharply to the apices.

Males examined from the following localities: Nova Scotia, Maine, Vermont, New York, North Carolina, and Wyoming.

***Tubifera brousi* (Williston) (Fig. 6)**

1882 *Eristalis brousi* Williston, Proc. Amer. Phil. Soc., 20: 323.
1886 *Eristalis brousi* Williston, Synop. N. A. Syrph., pp. 165-166.
1925 *Eristalis brousi* Curran, Canadian Entomologist 57: 50.
1925 *Eristalis brousi* Hull, Ohio Jour. Sci. 25: 310.
1930 *Eristalis brousi* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: This species has been recorded from Alaska to Maine and south to New Mexico.

The hypopygium of this species is characterized by the shape of the surstyli, and by the cerci being long, narrow, and gradually tapering to apices.

Males examined from the following localities: New Mexico, New Hampshire, Utah, Colorado, Wyoming, and New York.

***Tubifera latifrons* (Loew) (Fig. 7)**

1865 *Eristalis latifrons* Loew, Berl. Ent. Zeit., 6: 55.
1886 *Eristalis latifrons* Williston, Synop. N. A. Syrph., p. 164.
1925 *Eristalis latifrons* Hull, Ohio Jour. Sci., 25: 295.
1930 *Eristalis latifrons* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: A widespread species, more abundant in the southern half of the United States.

The hypopygium of this species is characterized by the knife-like shape of the superior lobes. The apical half of these lobes taper to a sharp upcurved point; dorsal margins blackly chitinized, slightly translucent below. The surstyli are deeply cleft medially forming two distinct lobes with the apical lobe much smaller and finger-like.

Males examined from the following localities: Leadville, Colorado, and one from the W. M. Wheeler collection contained in the American Museum of National History.

***Tubifera vinetorum* (Fabricius) (Fig. 8)**

1794 *Eristalis vinetorum* Fabricius, Ent. Syst., Suppl., p. 562.
1805 *Eristalis vinetorum* Fabricius, Syst. Antl., 235, 13.
1886 *Eristalis vinetorum* Williston, Synop. N. A. Syrph., p. 171.
1925 *Eristalis vinetorum* Hull, Ohio Jour. Sci., 25: 40.
1930 *Eristalis vinetorum* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Recorded from as far north as Indiana.

The rounded, undulate dorsal spur near the base of the superior lobes and the deeply cleft dorsal margins of the surstyli show the close relationship between this species and *obsoletus* (Wied.). *E. vinetorum*, however, may be separated from that species by the spade-like superior lobes.

Males examined from the following localities: Florida, Texas, Porto Rico, and Temax, N. Yucatan, Gaumer.

***Tubifera obsoletus* (Wiedemann) (Fig. 9)**

1830 *Eristalis obsoletus* Wiedemann, Auss. Zweifl. Ins., 2: 175.
1925 *Eristalis obsoletus* Hull, Ohio Jour. Sci., 25: 306.

1930 *Eristalis obsoletus* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Known from California and Arizona.

This species is characterized by having each of the inferior lobes broadly swollen at the basal third with the apical two-thirds abruptly constricted, long, narrow, and spur-like.

The description is based upon a single male from Sabino Basin, S. Catalina Mts., Arizona.

***Tubifera transversus* (Wiedemann) (Fig. 10)**

1828 *Eristalis transversus* Wiedemann, Auss. Zweifl. Ins., 2: 188-189.
1886 *Eristalis transversus* Williston, Synop. N. A. Syrph., p. 170.
1925 *Eristalis transversus* Hull, Ohio Jour. Sci., 25: 41.
1930 *Eristalis transversus* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Very common throughout the Atlantic States and west to Texas.

The general shape of the hypopygium in this species shows a close relationship to *dimidiatus* (Wied.), but the two can be readily separated by the shape of the superior lobes. The dorsal margins of the surstyli in *transversus* are cleft in such a manner as to form two distinct lobes; the apical lobe is small, spur-like, and attached to the base of the basal lobe.

Males examined from the following localities: Nova Scotia, Maine, Massachusetts, New York, and North Carolina.

***Tubifera dimidiatus* (Wiedemann) (Fig. 11)**

1828 *Eristalis dimidiatus* Wiedemann, Auss. Zweifl. Ins., 2: 180-181.
1886 *Eristalis dimidiatus* Williston, Synop. N. A. Syrph., p. 162.
1925 *Eristalis dimidiatus* Hull, Ohio Jour. Sci., 25: 295.
1930 *Eristalis dimidiatus* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Nova Scotia through the Atlantic States and west to Kansas.

This species differs from *transversus* in the shape of the superior lobes and the dorsal margins of the surstyli. The dorsal margins of the surstyli are cleft similar to those in *transversus*, but differs in that the small apical lobe appears as a hook-like process at the base of the apical third of the surstyli.

Males examined from the following localities: Nova Scotia, Maine, Massachusetts, and North Carolina.

***Tubifera pilosus* (Loew) (Fig. 13)**

1865 *Eristalis pilosus* Loew, Berl. Ent. Zeit., 6: 70.
1886 *Eristalis pilosus* Williston, Synop. N. A. Syrph., p. 174.
1925 *Eristalis pilosus* Hull, Ohio Jour. Sci., 25: 22.
1930 *Eristalis pilosus* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Known from Labrador and Alaska.

The surstyli of this species resemble those of *compactus* (Wlk.), but the squarely truncate apices of the superior lobes will at once distinguish the species.

Hypopygial description based upon a single male from Hopedale, Labrador.

***Tubifera compactus* (Walker) (Fig. 14)**

1849 *Eristalis compactus* Walker, List Dipt. Ins., 3: 619.
1886 *Eristalis compactus* Williston, Synop. N. A. Syrph., p. 169.
1925 *Eristalis compactus* Curran, Can. Ent., 57: 50.
1925 *Eristalis compactus* Hull, Ohio Jour. Sci., 25: 296.
1930 *Eristalis compactus* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Occurs in the northern part of the United States.

The superior lobes of *compactus* may be confused with those of *transversus*, but the definite bilobed dorsal margins of the surstyli in *transversus* will readily separate the two species.

Males examined from the following localities: Burke Falls, Ontario, and Caroline, New York.

***Tubifera bastardii* (Macquart) (Fig. 12)**

1842 *Eristalis bastardii* Macquart, Mem. Soc. Sci. Lille, p. 95.
1886 *Eristalis bastardii* Williston, Synop. N. A. Syrph., p. 168.
1925 *Eristalis bastardii* Hull, Ohio Jour. Sci., 25: 80.
1930 *Eristalis bastardii* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: A very common species throughout the eastern part of the United States.

This species is easily recognized by the distinct shape of the superior lobes. The apical third is roughly diamond-shaped, narrowly constricted at base and pointed at apex; dorso-apical margin coarsely serrated.

On the basis of the hypopygium no character or combination of characters were found by which *bastardii* could be separated from the specimens of *anthophorinus* (Fall.), *montanus* (Will.) (considered a synonym of *anthophorinus* by Hull (1925)), and *occidentalis* (Will.) which the author had before him when making this study. The close relationship of these species is apparent when the taxonomist attempts to separate them on the basis of external characters. Although it is not the author's desire nor the purpose of this paper to establish synonyms or varieties there are certain cases where such action should be carefully considered. The gradations in external characters noted in the numerous available specimens of *bastardii* and *anthonphorinus* strongly emphasize such considerations.

Numerous males examined from the following localities: Maine, Vermont, and New York.

***Tubifera anthophorinus* (Fallen)**

1817 *Syrphus anthophorinus* Fallen, Dipt. Suec. Syrph., 28, 21.
1925 *Eristalis anthophorinus* Hull, Ohio Jour. Sci., 25: 20.
1925 *Eristalis montanus* Hull, Ohio Jour. Sci., 25: 20.
1925 *Eristalis montanus* Hull, Ohio Jour. Sci., 25: 20. (Synonym of *anthophorinus*).
1930 *Eristalis anthophorinus* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Western part of the United States.

The hypopygium of this species is identical to that of *bastardii*. See discussion under that species.

Males examined from the following localities: Colorado, British Columbia, and Alberta.

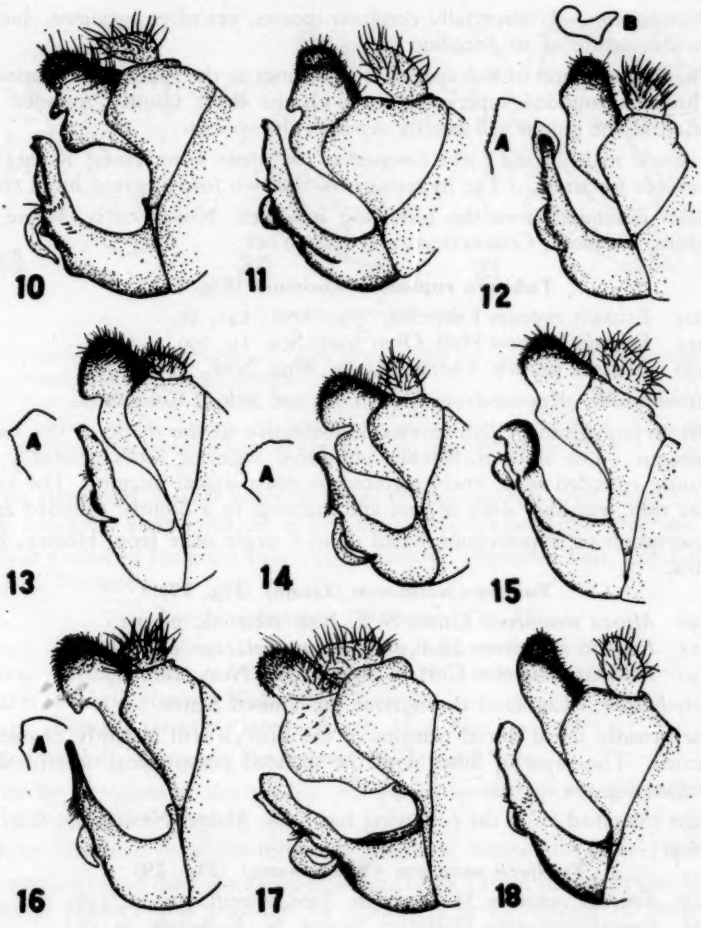
***Tubifera occidentalis* (Williston)**

1882 *Eristalis occidentalis* Williston, Proc. Amer. Phil. Soc., 20: 322.
1886 *Eristalis occidentalis* Williston, Synop. N. A. Syrph., p. 167.
1925 *Eristalis occidentalis* Hull, Ohio Jour. Sci., 25: 17.
1930 *Eristalis occidentalis* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: California and Washington.

A discussion of this species is given under *bastardii*. No differences could be found between the hypopygium of this species and that of *bastardii* and *anthophorinus*.

Only a single specimen from California was available for study.



HYPOPYGIA OF TUBIFERA

Fig. 10. *Tubifera transversus* (Wied.)
11. *Tubifera dimidiatus* (Wied.)
12. *Tubifera bastardii* (Macq.); A. dorso-apical margin of a superior lobe; B. cross-section at apex of surstylus.
13. *Tubifera pilosus* (Loew); A. apex of a superior lobe—enlarged.
14. *Tubifera compactus* (Wlk.); A. apex of a superior lobe enlarged to show the shallow dorsal notch.
15. *Tubifera tenax* (Linné)
16. *Tubifera rupium* (Fabr.); A. apex of a superior lobe—enlarged.
17. *Tubifera nemorum* (Linné)
18. *Tubifera flavipes* (Wlk.)

Tubifera tenax (Linne) (Fig. 15)

1758 *Musca tenax* Linne, Syst. Nat., 10th ed., p. 591.
1886 *Eristalis tenax* Williston, Synop. N. A. Syrph., p. 160.
1925 *Eristalis tenax* Hull, Ohio Jour. Sci., 25: 305.
1930 *Eristalis tenax* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: A universally common species, yet often localized, due probably to the nature of its breeding places.

The hypopygium of this species is as distinct as the species is common. The short broadly rounded superior lobes with the short bluntly rounded dorsal projection at the apices will readily separate the species.

A single male of the form *campestris* (Meigen) from Hong Kong, China, was available for study. The hypopygia of the two forms agreed in all respects.

Males examined from the following localities: Nova Scotia, Maine, New Hampshire, Vermont, Connecticut, and New York.

***Tubifera rupium* (Fabricius) (Fig. 16)**

1805 *Eristalis rupium* Fabricius, Syst. Antl., 241, 38.
1925 *Eristalis rupium* Hull, Ohio Jour. Sci., 25: 299.
1930 *Eristalis rupium* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Known from New York and British Columbia.

The hypopygium of this species is distinctive in the shape of the lobes of the aedeagus. The smooth, blackly chitinized superior lobes gradually taper to a bluntly rounded apex; finely serrated on dorso-apical margin. The inferior lobes are thin, leaf-like, wide at base and tapering to a bluntly rounded apex.

Description of hypopygium based upon a single male from Hedley, British Columbia.

***Tubifera nemorum* (Linné) (Fig. 17)**

1758 *Musca nemorum* Linné, Syst. Nat. 10th ed., p. 591.
1925 *Eristalis nemorum* Hull, Ohio Jour. Sci., 25: 301.
1930 *Eristalis nemorum* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Common throughout the United States.

The broadly lobed dorsal margins of the surstyli will instantly characterize this species. The superior lobes with the serrated dorso-apical notch will also aid in separating the species.

Males examined from the following localities: Maine, New York, Utah, and Wyoming.

***Tubifera saxorum* (Wiedemann) (Fig. 19)**

1828 *Eristalis saxorum* Wiedemann, Auss. Zweifl. Ins., 2: 158.
1886 *Eristalis saxorum* Williston, Synop. N. A. Syrph., p. 163.
1925 *Eristalis saxorum* Hull, Ohio Jour. Sci., 25: 295.
1930 *Eristalis saxorum* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: A common, well known species, seemingly limited to the northeastern states.

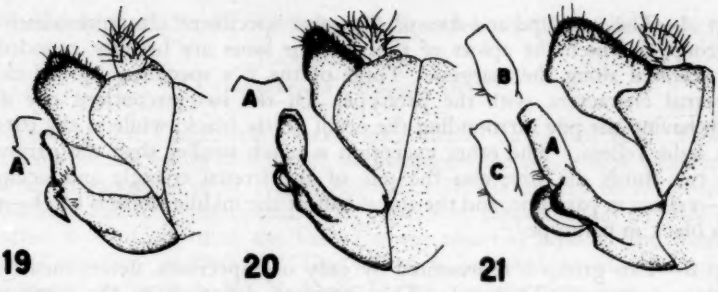
The surstyli of this species closely resemble those of *obscurus* (Loew), but the two species can be readily separated on the basis of the superior lobes. The superior lobes of *saxorum* are slightly constricted near the apical fourth and curved upward. Dorsal margins near apices with a small curved spur.

Males examined from the following localities: Maine, and Massachusetts.

***Tubifera obscurus* (Loew) (Fig. 20)**

1865 *Eristalis obscurus* Loew, Berl. Ent. Zeit., 6: 67.
1886 *Eristalis obscurus* Williston, Synop. N. A. Syrph., p. 175.
1925 *Eristalis obscurus* Hull, Ohio Jour. Sci., 25: 300.
1930 *Eristalis obscurus* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Maine to Colorado; also known from Alaska.



HYPOPYGIA OF TUBIFERA

Fig. 19. *Tubifera saxorum* (Wied.); A. apex of a superior lobe enlarged to show small curved dorsal spur and serrate margin.
20. *Tubifera obscurus* (Loew); A. apex of a superior lobe—enlarged.
21. *Tubifera hirtus* (Loew); A. drawn from paratype—representative of group *A*; B. superior lobe representative of Group *B*; C. same for group *C*.

The ellipsoidal shaped superior lobes of this species with their truncate, slightly concaved apices will aid in separating this species from *saxorum.*

Males examined from the following localities: Tennessee Pass, Colorado, and Winnipeg, Manitoba.

***Tubifera flavipes* (Walker) (Fig. 18)**

1849 *Eristalis flavipes* Walker, List Dipt. Ins., 3: 633.
1886 *Eristalis flavipes* Williston, Synop. N. A. Syrph., p. 168.
1925 *Eristalis flavipes* Hull, Ohio Jour. Sci., 25: 23.
1930 *Eristalis flavipes* Curran, Amer. Mus. Nov., 411: 3-7.

Distribution: Common throughout the United States.

The hypopygium of this readily recognized species is characterized by the shape of the superior lobes.

Males examined from the following localities: Maine and New Hampshire.

A single male of the form *melanostomus* (Loew) from the American Museum of Natural History was available for study. The hypopygia of both forms agreed in all respects.

***Tubifera hirtus* (Loew) (Fig. 21)**

1865 *Eristalis hirtus* Loew, Berl. Ent. Zeit., 6: 66.
1886 *Eristalis hirtus* Williston, Synop. N. A. Syrph., p. 162.

Distribution: Pacific States and as far east as Kansas.

In the study of this species the author is indebted to Dr. Bequaert who made available to him a male paratype from the Loew collection in the Museum of Comparative Zoology at Cambridge, Mass. The specimen bore the blue label "Californ. Edwards". The drawing, figure 21A, was made from the hypopygium of this specimen. Also available for study were four specimens from the United States National Museum, three specimens from the American Museum of Natural History, and a single specimen collected in Wyoming by the author.

In general the hypopygia of all of these specimens were similar except for the apices of the superior lobes. On the basis of these the author found three separate and distinct groups which are represented by A, B, and C in figure 21. A short discussion of each group is given below.

Group A—The paratype and five of the other specimens are representatives of this group in which the apices of the superior lobes are broadly rounded and finely serrated along the margins. Three of the five specimens agreed closely, in external characters, with the paratype. Of the two exceptions one differs only in having the pile surrounding the ocelli nearly black, while in the paratype it is a light yellow. The other exception is much smaller than the paratype—about two-thirds the size; also the pile of the frontal triangle and occiput is black—yellow in paratype, and the apical half of the middle tibiae is black—apical fourth black in paratype.

Group B—This group is represented by only one specimen, determined by Dr. Curran as *temporalis* Thomson. This specimen differs from the paratype, in external characters, by having the pile surrounding the ocelli a dark brown. The squarely truncate apices of the superior lobes will readily distinguish this group.

Group C—The hook-like spur at the dorso-apical margins of the superior lobes with the apices rounded below will characterize the group. Two specimens labelled as *temporalis* Thomson fall in this group, and differ from the paratype by having the ocellar pile a dark brown.

Males examined from the following localities: Idaho, Wyoming, Colorado, New Mexico, California (paratype), and Alaska.

Literature

Balfour-Browne, F. (1932). A textbook of practical entomology. London, 190 pp., 116 figs.

Berlese, A. (1909). Gli insetti. Milano, 1909. Vol. 1, 1004 pp., 1292 figs.

Crampton, G. C. (1942). The external morphology of the Diptera *In* The Diptera or True Flies of Connecticut. Part VI. *State Geol. and Nat. Hist. Surv. Bull. 64*, pp. 10-162.

Curran, C. H. (1925). Notes on some species of the genus *Eristalis* (Syrphidae, Diptera). *Can. Ent. 57*: 50.

———— (1930). New species of Eristalinae with notes (Syrphidae, Diptera). *Amer. Mus. Nov. No. 411*, 27 pages.

Hardy, G. H. (1944). The copulation and the terminal segments of Diptera. *Proc. R. Ent. Soc. Lond. (A) 19, Pts. 4-6*, pp. 52-65.

Hull, F. M. (1925). A review of the genus *Eristalis* Latreille in North America. *Ohio Jour. Sci. 25*: 11-45; 285-312.

Hunter, W. D. (1896). A contribution to the knowledge of North American Syrphidae. *Can. Ent. 28*: 87-101.

Johnson, C. W. (1925). Diptera of the Harris Collection. *Proc. Bost. Soc. N.H. 38*: 81-82.

Metcalf, C. L. (1921). The genitalia of the male Syrphidae: Their morphology, with especial reference to its taxonomic significance. *Ann. Ent. Soc. Amer. 14*: 169-214.

Osten Sacken, C. R. (1876). A list of the North American Syrphidae. *Bul. Buffalo Soc. Nat. Sci. 3*: 38-71.

———— (1877). Western Diptera. Descriptions of new genera and species of Diptera from the Region west of the Mississippi, and especially from California. *Bul. U.S. Geol. and Geog. Surv. Ter., ser. 2, 3*: 189-354.

Stone, A. (1941). The generic names of Meigen 1800 and their proper application. *Ann. Ent. Soc. Amer. 34*: 404-418.

Verrall, G. H. (1901). Syrphidae. British Flies. *8*: 127-691.

Williston, S. W. (1882). Contribution to a monograph of North American Syrphidae. *Proc. Amer. Phil. Soc. 20*: 299-332.

———— (1886). Synopsis of North American Syrphidae. *Bul. U.S. Nat. Mus. No. 31*, XXVII and 336 pages.

A Review of R. C. Treherne's Species of Thysanoptera

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University of California, Davis

One of the few Canadian entomologists to study thrips was R. C. Treherne who was one of the group of workers to investigate the pear thrips when it first became an economic pest in North America. In the course of his work he collected and studied thysanoptera. His collection, supplemented by exchanges with other workers, formed the basis for the material now in the Canadian National Collection at Ottawa. The writer is indebted to curators of this collection and particularly T. N. Freeman, for the generous loan of valuable specimens for study, particularly the types of Treherne. The Moulton collection is now deposited at the San Francisco Academy of Science, Golden Gate Park, San Francisco, California. We also wish to thank Dr. E. S. Ross, curator, for the opportunity of studying the types of *Taeniothrips tahoei* Moulton, *Tae. pingreei* Moulton, *Tae. aureus* Moulton, and *Frankliniella californica* Moulton.

Since Treherne described his four new species, several hundred additional new forms have been described from North America and it is becoming increasingly difficult for new workers to identify the insects of this group. It is thought that this condition will be made easier if the older species are studied, redescribed and illustrated in light of our present concepts and the relative value of characters originally overlooked or considered of minor importance when only a small number of species in a group were known.

Aeolothrips auricestus Treherne

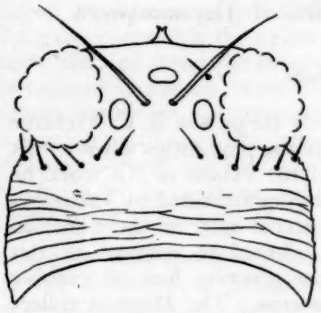
1919. Treherne, R. C.; Canad. Ent. 51 (8-9): 184-185, Plate XV, figs. 6, 7; Plate XVI, fig. 1.
1921. Treherne, R. C.; Proc. Ent. Soc. British Columbia. No. 15, System. Ser. pp. 7, 11. (Feb. 1920).
1923. Watson, J. R.; Fla. Agr. Exp. Sta. Bul. 168: 25-26.
1924. Treherne, R. C.; Canad. Ent. 56 (4): 82.
1929. Moulton, D.; Canad. Ent. 61: 286.
1948. Bailey, S. F.; Fla. Ent. 31 (2): 49.

To our knowledge this species has been known only from the original specimens. Recently, the writer was fortunate to make two collections as follows: Naches, Washington, sweeping grass at roadside, June 19, 1948; Ashland, Oregon, beating *Ceanothus*, June 22, 1948.

Additions to the original description with figures 4, 12, and 16, are offered herewith:

Female. The extreme base of the fore wing brown as is the base of the scale. Legs unicolorous with the exception of the fore tibiae and tarsi which are lighter brown. The brachypterous form has a light grey band on wing stub near tip. Spines on the mesocutum and sensory areas on third antennal segment are larger on the brachypterous form than on the macropterous form.

Allotype. The male was not collected or described by Treherne. In the collection made at Naches, Washington, two brachypterous males were taken. This sex is much smaller and lighter colored than the female. The terminalia are with claspers (see fig. 12) as in *fasciatus*. Abdominal segments II-VI are orange, VII brownish orange. Eyes prolonged ventrally. Head 130 microns long and 162.5 microns wide. Total length of body 1.040 mm. The two male specimens are in the writer's collection.



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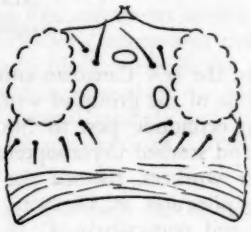

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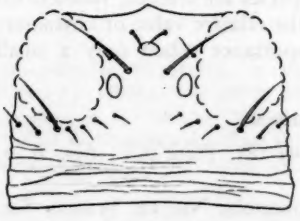

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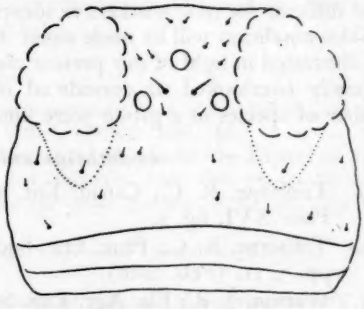

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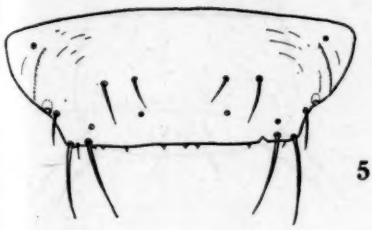
FIG. 1. *Taeniothrips orionis* Treherne. Dorsum of head of female, holotype.
FIG. 2. *Taeniothrips lemanis* Treherne. Dorsum of head of female, paratype.
FIG. 3. *Frankliniella nubila* Treherne. Dorsum of head of female, holotype.
FIG. 4. *Aeolothrips auricestus* Treherne. Dorsum of head of female, brachypterous, paratype.

Taeniothrips orionis Treherne

1924. *Taeniothrips orionis.* Treherne, R. C.; Canad. Ent. 56(4): 86-87. Figure on p. 87.
1927. *Taeniothrips tahoei.* Moulton, D.; Bul. Brook. Ent. Soc. 22 (4): 190-191. Pl. XI, fig. 2.
1927. *Taeniothrips pingreei* Moulton, D.; Bul. Brook. Ent. Soc. 22 (4): 191-192.
1933. *Taeniothrips orionis.* Steinweden, J. B.; Trans. Amer. Ent. Soc. 59: 284.
1948. *Taeniothrips orionis.* Bailey, S. F.; Fla. Ent. 31 (2): 49.

This large distinctive *Taeniothrips* appears to be commonly found at high elevations in the spring and summer in the flowers of various shrubs and trees. In general appearance it is much like *vulgatissimus* Haliday, 1836, which is collected in the same environment. It may be readily separated from *vulgatissimus* by the very long inter-ocellar bristles which are inserted close together and between the posterior ocelli and slightly anterior to a line between their centres (see fig. 1). The mid-lateral bristles on the pronotum (see fig. 10) are shorter in *vulgatissimus* than in *orionis*. Also the deep indentation of the cheeks imme-



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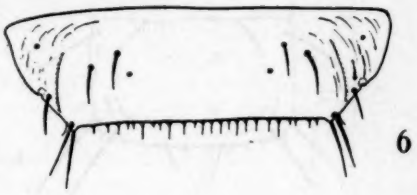

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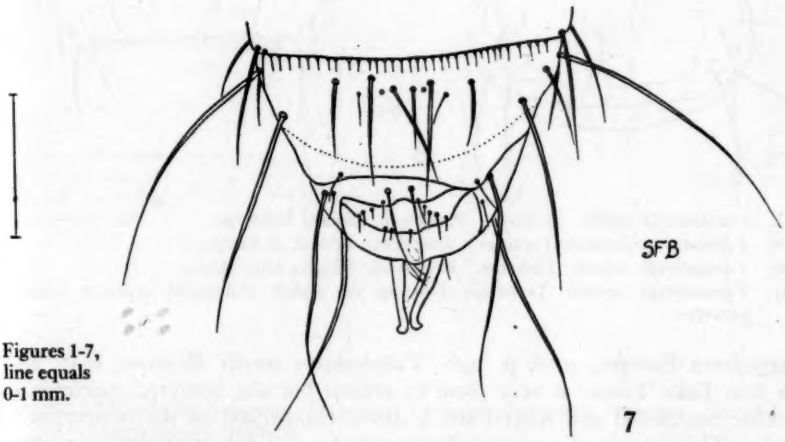

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Figures 1-7, line equals 0·1 mm.

FIG. 5. *Frankliniella nubila* Treherne. Dorsum of eighth abdominal segment, female, holotype.

FIG. 6. *Taeniothrips lemanis* Treherne. Dorsum of eighth abdominal segment, female, holotype.

FIG. 7. *Taeniothrips orionis* Treherne. Terminal abdominal segments (dorsal) of male, allotype.

diately behind the eyes is a distinctive characteristic of *orionis* (see fig. 1). When a series of specimens is studied it is noted that the number of distal bristles on the fore vein of the fore wing varies from two to four with an average number of three. The comb on the posterior margin of the dorsum of the eighth abdominal segment, is long and complete (see fig. 11).

The male of *orionis* was briefly described by Treherne but was not figured. We have illustrated the terminal abdominal segments of the allotype (fig. 7) for convenience of comparison with other species. We have compared the male allotypes of *orionis*, *pingreei*, and the unique male of *tahoei* and find them identical. We also have a male from near the type locality of *tahoei* which is the same. The varying degrees of contraction of the mounted specimens apparently accounts for the synonymy.

It should be noted that in the original description *orionis* was compared with *pallipennis* Uzel which has since been synonymized with *vulgatissimus* (Priesner.

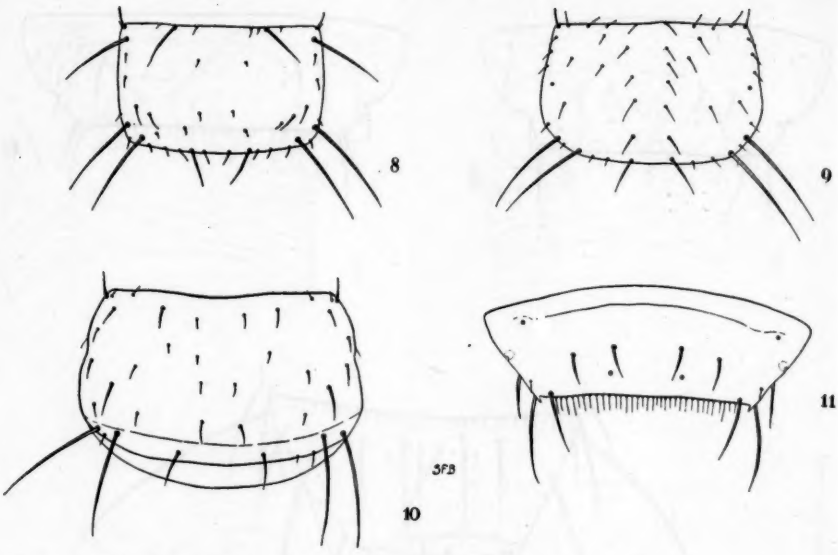


FIG. 8. *Frankliniella nubila* Treherne. Pronotum, female, holotype.
FIG. 9. *Taeniothrips lemanis* Treherne. Pronotum, female, holotype.
FIG. 10. *Taeniothrips orionis* Treherne. Pronotum, female, holotype.
FIG. 11. *Taeniothrips orionis* Treherne. Dorsum of eighth abdominal segment female, paratype.

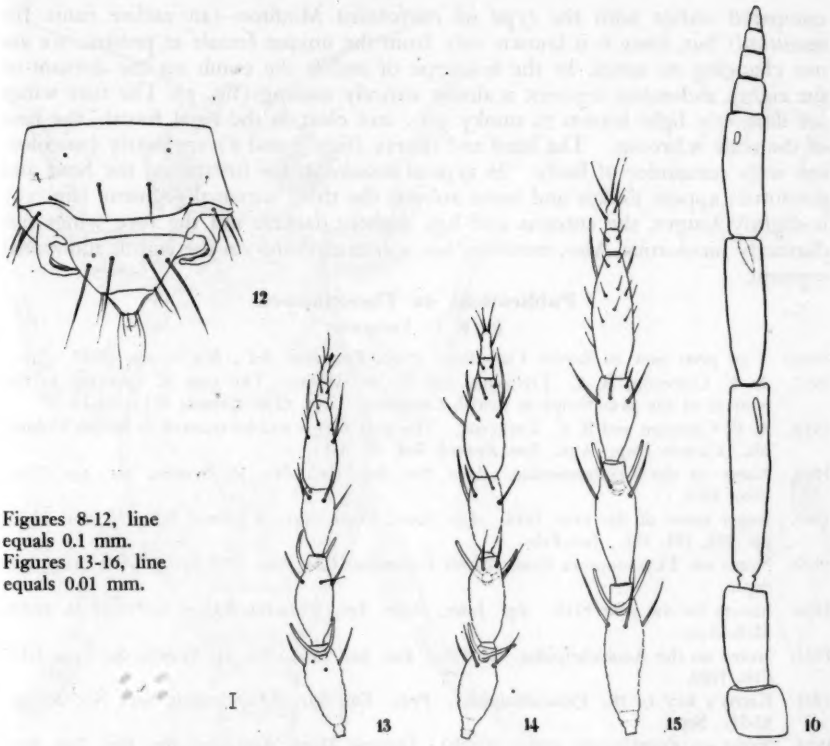
Thysanoptern Europas, 1926, p. 296). *Taeniothrips aureus Moulton,* 1946, also taken near Lake Tahoe, is very close to *orionis* but the holoytpe specimen is somewhat contracted and teneral and a direct comparison of the two types is difficult. The antenna of *orionis* is illustrated (fig. 15) for convenience in comparing closely related forms.

Taeniothrips orionis is known to the writer from the following collections (in addition to those of Treherne): Colorado: Pingree Park, *Solidago decumbens, Anaphalis subalpina, Solidago corumbosa, Erigeron asper,* C. P. Gillette and M. A. Palmer. Rocky Mt. Nat'l. Park. flowers of all plants, F. Andre. Wyoming: Centennial, spruce, E. Fichter. Teton Pass Summit, host unknown, Knowlton and Thornby. Grand Teton Nat'l. Park, Jenny Lake, sweeping, R. M. Bohart. Montana: Glacier Nat'l. Park, Logan Pass Summit, wild parsnip, G. F. Knowlton. Washington: Mt. Ranier Nat'l. Park, ash flowers, S. F. Bailey. California: Yosemite Nat'l. Park, Luken's Lake, *Veratrum Californica,* M. A. Stewart. Tamarack Lake, Eldorado County, *Polygonum alpinum,* E. O. Essig. Lake Tahoe, grass, D. Moulton.

Taeniothrips lemanis Treherne

1924. Treherne, R. C.; Canad. Ent. 56 (4): 87-88.
1933. Steinweden, J. B.; Trans. Amer. Ent. Soc. 59: 288.
1948. Bailey, S. F.; Fla. Ent. 31 (2): 49.

This species is much more difficult to separate from its relatives than *orionis.* Here again *lemanis* is close to *vulgatissimus* in general appearance. However, it is smaller (figs. 2, 9) particularly in the length of the third antennal segment (fig. 14). The comb is sparse and not strongly developed (fig. 6) and the mid-lateral



Figures 8-12, line equals 0.1 mm.
Figures 13-16, line equals 0.01 mm.

FIG. 12. *Aeolothrips auricestus* Treherne. Terminal abdominal segments (dorsal), male, brachypterous, allotype.
FIG. 13. *Frankliniella nubila* Treherne. Antennal segments III-VIII, female, holotype.
FIG. 14. *Taeniothrips lemanis* Treherne. Antennal segments III-VIII, female, paratype.
FIG. 15. *Taeniothrips orionis* Treherne. Antennal segments III-VIII, female, paratype.
FIG. 16. *Aeolothrips auricestus* Treherne. Antennal segments I-IX, female, brachypterous, paratype.

bristles on the pronotum are shorter than in *vulgatissimus*. (These bristles are broken off in the holotype). Treherne (page 88) mentioned that on the eighth abdominal segment "lateral processes readily seen" by which he apparently meant the minute ridges which support a row of micro-setae (see fig. 6), which are also present in *vulgatissimus*.

We add the following new record for *lemanis* which is definitely not a commonly collected species: California: Yosemite Valley, May 30, 1938, leaves of *Acer macrophyllum* and *Manzanita* leaves, S. F. Bailey.

***Frankliniella nubila* Treherne**

1924. Treherne, R. C.; Canad. Ent. 56 (4): 84-86.
1948. Moulton, D.; Revis. de Ent. 19 (1-2): 72. Fig. 24, a,b,c.
1948. Bailey, S. F.; Fla. Ent. 31 (2): 49.

This thrips belongs in the *intonsa* group (Hood. 1925. Bul. Brook. Ent. Soc. 20 (2): 75-76), *intonsa* series (Moulton, 1948. Revis. de Ent. 19 (1-2): 59, 72), of the large and very difficult genus *Frankliniella*. As had been pointed out by Moulton, it is very close to *moultoni* Hood, perhaps only a variety. We have

compared *nubila* with the type of *californica* Moulton (an earlier name for *moultoni*) but, since it is known only from the unique female at present, we are not changing its status. In the holotype of *nubila* the comb on the dorsum of the eighth abdominal segment is almost entirely missing (fig. 5). The fore wings are distinctly light brown to smoky grey and clear in the basal fourth, the base of the scale is brown. The head and thorax (figs. 3 and 8) are nearly concolorous with remainder of body. In typical *moultoni*, the bristles on the head and pronotum appear darker and more robust, the third antennal segment (fig. 13) is slightly longer, the antenna and legs slightly darker, and the fore wings not distinctly bicolorous. Also, *moultoni* has a distinct comb on the eighth abdominal segment.

Publications on Thysanoptera

By R. C. Treherne

1916. Two pests new to British Columbia. *Proc. Ent. Soc. B.C., No. 9*, pp. 79-82.
1917. A. E. Cameron, R. C. Treherne, and E. W. White. The cost of spraying in the control of the pear thrips in British Columbia. *Agr. Gaz. Canada 4*(1): 13-16.
1918. A. E. Cameron and R. C. Treherne. The pear thrips and its control in British Columbia. Canada Dept. Agr., *Ent. Branch Bul. 15*: 1-51.
1919. Notes on the Aeolothripidae. *Proc. Ent. Soc. B.C.*, No. 12, System. Ser., pp. 27-33. Feb., 1918.
1919. Insect notes of the year 1918. *Agr. Jour., Dept. Agr., Victoria, B.C. III, nos. 11-12*, pp. 258, 281, 301. Jan.-Feb.
1919. Notes on Thysanoptera from British Columbia. *Can. Ent. 51*(8-9): 181-190. Aug. and Sept.
1920. Insects for the year 1919. *Agr. Jour., Dept. Agr., Victoria, B.C., 5 (1-2)*: 25-26, 52-56. Mch.-Apr.
1921. Notes on the Aeolothripidae. II. *Proc. Ent. Soc.* B.C., No. 16, System. Ser., pp. 7-15. Feb. 1920.
1922. Karny's key to the Phloeothripidae. *Proc. Ent. Soc.* B.C., System. Ser., No. 20, pp. 42-55. Sept.
1923. Notes on *Frankliniella tritici* (Fitch). *Ontario Dept. Agr. 53rd An. Rpt. Ent. Soc. Ont.*, pp. 39-43. 1922.
1924. Thysanoptera known to occur in Canada. *Can. Ent. 56*(4): 82-88.

The Nymph of *Ephemerella excrucians* Walsh[1]

By Justin W. Leonard
Michigan Department of Conservation

The taxonomic status of *Ephemerella excrucians* Walsh was recently discussed by Burks (1947), who also stated that destructive ecological changes have drastically altered the type locality of the species. Special interest attaches, therefore, to two male specimens of *Ephemerella* which I reared from nymphs taken in the Au Sable River, Crawford County, Michigan, and which Dr. Burks has determined as *E. excrucians*.

The Au Sable River at the collecting site is about 80 feet wide, and flows with a midstream velocity of 2.5-3 feet per second over a bottom of glacial sand and gravel. The water is hard, and derived almost entirely from springs and seepage areas. Both nymphs were taken from a gravel bar covered with about 14 inches of water, and were at once seen to be distinct from other *invaria*-type nymphs in the sample. Color notes were made of the living specimens before they were reared to the imaginal stage. The description to follow was made

[1]Contribution from the Institute for Fisheries Research.

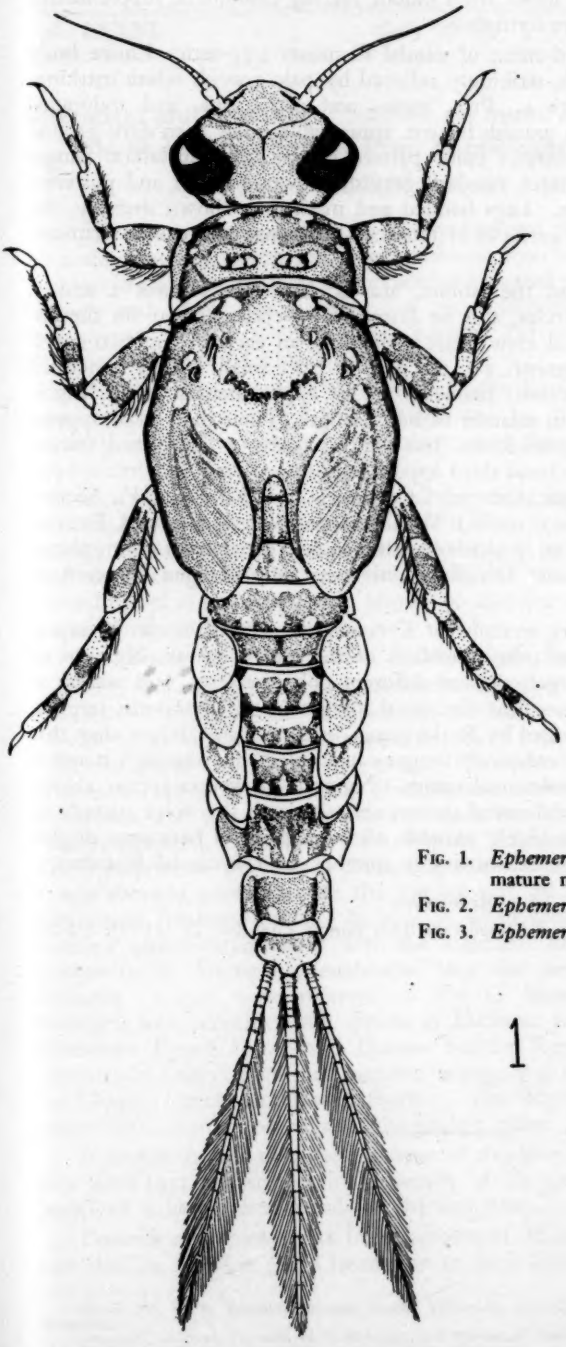


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FIG. 1. *Ephemerella excrucians*, dorsal view of mature male nymph.
FIG. 2. *Ephemerella excrucians*, labium of nymph.
FIG. 3. *Ephemerella excrucians*, maxilla of nymph.

1

from the exuviae, preserved intact from indoor rearing containers, supplemented by notes taken on the mature nymphs.

Nymph. Length of body 6 mm.; of caudal filaments 2.75 mm. Entire body very dark gray, nearly black, strikingly relieved by pale grayish white markings dorsally as shown in Figure 1. Pro-, meso- and metasterna, and abdominal sternites 1-6 and 10 medium grayish brown, appreciably paler than dark ground color of drosum, without distinct color pattern except for pale lateral flanges of abdomen; abdominal sternites 7-9 dark grayish brown, anterior and posterior angles of lateral flanges pale. Legs banded and marked as shown dorsally, the pattern indistinct on ventral surfaces of femora. Antennae and caudal filaments pale.

The maxillary palp, and the labium, are as shown in Figures 2 and 3. The head is devoid of tubercles, and no horns or tubercles appear on the abdominal tergites. Each tarsal claw bears 6 denticles in each of the two specimens. Gills are borne on segments 3-7; the pair on 7 are small, largely concealed by those on 6. The three caudal filaments are of approximately equal length, unbanded, and rather short in relation to body length. Their pale color appears unrelieved under usual magnifications, but viewed under a compound microscope the articulations in the basal third appear reddish brown.

Material examined. Michigan, Crawford County, T. 26 N., R. 2 W., Section 13, Au Sable River, June 12-13, 1948, J. W. Leonard and F. A. Leonard. Exuviae of two male nymphs, preserved in alcohol with imagoes reared from them; placed in the collection of the Insect Division, University of Michigan Museum of Zoology.

On superficial characters, nymphs of *Ephemerella excrucians* can be separated readily from nymphs of other members of the *invaria* group. Nymphs of *subvaria* and *rotunda* are larger, present different color patterns, and possess at least rudimentary paired spines near the apical margin of the abdominal tergites. The nymph of *argo*, as described by Burks (1947) is appreciably larger than that of *excrucians* and bears proportionately longer caudal filaments, although it agrees with *excrucians* in lacking abdominal spines. Nymphs of *invaria* appear always to bear at least vestiges of abdominal spines; and although the color pattern of *invaria* nymphs appears to be highly variable, all color phases I have seen display prominent transverse bands, three to five in number, on the caudal filaments.

Reference

Burks, B. D. 1947. New species of *Ephemerella* from Illinois. *Can. Ent.*, *79* (11-12): 232-236. Figs. 1-7.